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DANIEL H. COLE*

The *Stern Review* and Its Critics: Implications for the Theory and Practice of Benefit-Cost Analysis

ABSTRACT

The United Kingdom Treasury's Stern Review: The Economics of Climate Change was the first economic analysis of climate change to be sponsored by a government agency. The Review proved highly controversial because it reached dramatically different conclusions and policy recommendations than most earlier economic analyses of climate change. Several prominent economists, including William Nordhaus, Partha Dasgupta, Richard S.J. Tol, Robert Mendelsohn, and Martin Weitzman, have criticized the Stern Review on various grounds, including its damage estimates and selection of parameter values, including the utility discount rate and the elasticity of marginal utility, which affect the interest rate at which future costs and benefits are discounted to present value. This article summarizes the Stern Review and its critiques and assesses them from a process-oriented perspective to determine what they can teach us, positively and negatively, about how benefit-cost analyses should (or should not) be done.

Every cost-benefit analysis is an exercise in subjective uncertainty. If, as the *Stern Review* puts it, "climate change is the greatest externality the world has ever seen," then a cost-benefit calculation of what to do about it is the greatest exercise in Bayesian decision theory that we economists have ever performed.

Martin Weitzman¹

* R. Bruce Townsend Professor of Law, Indiana University School of Law—Indianapolis. The author is grateful to Martin Weitzman for providing successive drafts of various working papers; to Peter Grossman, Ian Hodge, Kerry Krutilla, Elinor Ostrom, Tim Swanson, Richard Tol, and Martin Weitzman for their helpful comments and suggestions on drafts of this paper; to the participants in the 2007 Benefit-Cost Analysis Conference at the University of Washington, especially the conference organizer Richard Zerbe; and to audiences at the UCLA Law School, the Canadian Law and Economics Association, and the Midwest Law and Economics Association.

1. Martin Weitzman, *A Review of the Stern Review on the Economics of Climate Change*, 45 J. ECON. LITERATURE 703, 717 (2007).

I. INTRODUCTION

In 2003, the United Kingdom's Chancellor of the Exchequer, Gordon Brown, appointed Nicholas Stern, an Oxford economist and former World Bank chief economist and senior vice president, as second permanent secretary at Her Majesty's (HM) Treasury. Two years later, Chancellor Brown asked Secretary Stern to head up an official governmental review of the economics of climate change. The UK Treasury published the *Stern Review* on the Economics of Climate Change on October 30, 2006.² It was not the first benefit-cost analysis (BCA) on climate change ever,³ but it was the first such analysis to be issued with the imprimatur of a major government. Consequently, the *Stern Review* had unusually high political salience and potential to influence policy.

Unsurprisingly, politicians and NGOs that favor rapid and strong action to mitigate greenhouse gas emissions greeted the nearly 600-page *Stern Review* with uncritical adulation, while climate-change skeptics summarily bashed it.⁴ More serious academic critiques of the *Review* were not long in coming. Several well-respected economists have argued that the *Review's* assumptions, arguments, and recommendations are seriously flawed, even biased,⁵ while others have read the *Review* more generously.⁶

2. NICHOLAS STERN, THE ECONOMICS OF CLIMATE CHANGE: THE STERN REVIEW (2007), available at http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm.

3. See, e.g., WILLIAM R. CLINE, THE ECONOMICS OF GLOBAL WARMING (1992); Robert O. Mendelsohn et al., *Country-Specific Market Impacts of Climate Change*, 45 CLIMATIC CHANGE 553 (2000); WILLIAM D. NORDHAUS & JOSEPH G. BOYER, WARMING THE WORLD: ECONOMIC MODELS OF GLOBAL WARMING (2000).

4. CTR. FOR SCI. & PUBLIC POL'Y, THE STERN REPORT: SOME EARLY CRITICISMS (2006), http://ff.org/centers/csspp/pdf/20061104_stern.pdf; LEONARDO RIBÓN, REVIEW OF THE REACTIONS GENERATED BY THE RELEASE OF THE STERN REVIEW: THE ECONOMICS OF CLIMATE CHANGE (2006), <http://www.global.rmit.edu.au/GS@RMIT%20Review%20of%20Reactions%20to%20Stern%20Dec06.pdf>.

5. See, e.g., William D. Nordhaus, *A Review of the Stern Review on the Economics of Climate Change*, 45 J. ECON. LITERATURE 686 (2007); Partha Dasgupta, *Commentary: The Stern Review's Economics of Climate Change*, 199 NAT'L INST. ECON. REV. 4 (2006); David Maddison, *Further Comments on the Stern Review* (unpublished manuscript on file with author); Robert O. Mendelsohn, *A Critique of the Stern Report*, 29 REGULATION 42 (Winter 2006-2007); Richard S.J. Tol, *The Stern Review of the Economics of Climate Change: A Comment*, 17 ENERGY & ENV'T 977 (2006); Gary W. Yohe, *Some Thoughts on the Damage Estimates Presented in the Stern Review – An Editorial*, 6 INTEGRATED ASSESSMENT J. 65 (2006); Gary W. Yohe & Richard S.J. Tol, *The Stern Review: Implications for Climate Change*, 49 ENVIRONMENT 36 (2007).

6. See, e.g., John Quiggin, *Stern and the Critics on Discounting* (Dec. 20, 2006) (unpublished manuscript), available at <http://johnquiggin.com/wp-content/uploads/2006/12/sternreviewed06121.pdf>; Kenneth J. Arrow, *Global Climate Change: A Challenge to Policy*, 4 ECONOMISTS' VOICE (Special Issue) 1 (2007), available at www.bepress.com/ev (go to "Special Issues: Climate Change"); Thomas Sterner & U. Martin Persson, *An Even Sterner Review*:

In perhaps the most nuanced and interesting of all the reviews, Martin Weitzman deftly criticizes the *Stern Review's* assumptions and analysis, but goes on to suggest why, ultimately, the *Review's* conclusions might be sound.⁷ Weitzman's analysis, in particular, has important implications for the practice of BCA as it applies to policies like climate change, which involve long time horizons, potentially catastrophic levels of harm, and very high levels of uncertainty.

One purpose of this article is to critically assess the *Stern Review* and its various reviews. Another is to explain that the disagreements over the quality of the *Stern Review* (among serious scholars without ostensible political or ideological agendas) largely reflect disagreements about how BCAs generally should – and should not – be done. To that end, the article focuses on the *Stern Review's* BCA from a process-oriented perspective and asks what producers and consumers of benefit-cost analyses can learn from the *Stern Review* and its critics about the theory and practice of benefit-cost analysis. The lessons are several, including many negative lessons about how benefit-cost analyses should *not* be done. Less obvious, but just as important, are one or two positive lessons from the *Stern Review*. The lessons, both positive and negative, relate to the selection of parameter values, including discount rates, and methods of estimating damages.

Section 2 explicates the *Stern Review's* model, arguments, conclusions, and recommendations. Section 3 examines the scholarly commentary on the *Stern Review*, most of which has been highly critical. In particular, commentaries have criticized the *Stern Review's* damage estimates and selection of parameter values, the elements that determine the social discount rate (the pure rate of time preference, the elasticity of marginal utility, and the rate of growth of consumption). Section 4 explores the implications of those criticisms, as well as the arguments made by Sir Nicholas Stern and his co-authors, for the theory and practice of BCA.

Although there is no official set of “best practices” for BCA, this article operates on the assumption that virtually all economists would agree that transparency and replicability are the twin sine qua non of BCA.⁸ More than anything else, the former requires that assumptions are explicit and the later requires that all relevant data are provided so that other analysts can

Introducing Relative Prices into the Discounting Debate 1–21 (Resources for the Future, Discussion Paper No. 07-37, 2007), Eric Neumayer, A Missed Opportunity: The *Stern Review* on Climate Change Fails to Tackle the Issue of Non-Substitutable Loss of Natural Capital (Apr. 2007) (unpublished manuscript), available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=980740.

7. Weitzman, *supra* note 1, at 705.

8. For a history of BCA in the United States (at the federal level) and an assessment of current practices in light of potential “best practices,” see Daniel H. Cole, “Best Practice” Standards for Regulatory Benefit-Cost Analysis, 23 RES. L. & ECON. 1 (2007).

verify the calculations. The article concludes with some thoughts about the *Stern Review's* overall significance for both BCA methodology and the economic analysis of climate change.

II. A SUMMARY OF THE STERN REVIEW

The *Stern Review* does three things: (1) assesses the likely costs of climate change up to 2200 under a "business as usual" (BAU) policy, where nothing is done to control emissions rates or atmospheric concentrations of greenhouse gases (GHGs); (2) estimates the costs and benefits of various levels of emissions mitigation and climate stabilization; and (3) evaluates policy options in light of the analyses from (1) and (2).

A. The PAGE2002 Model

Assessing the costs of climate change requires a special kind of model that integrates scientific and economic information about GHG emissions, atmospheric concentrations, and impacts. The goal of an "integrated assessment model" (IAM) is to simulate the process of climate change starting from GHG emissions through atmospheric concentrations to climate effects and ultimately the socio-economic impacts of climate change.⁹ The *Stern Review* uses an IAM developed by Chris Hope called PAGE2002.¹⁰ Chapter 6 of the *Stern Review* provides some (but not all¹¹) relevant details of the PAGE2002 model and how it was employed to derive climate change damage functions under various GHG emission trajectories.

The model measures socio-economic impacts of climate change in terms of differential per capita income growth rates under various scenarios ranging from zero climate change, at one extreme, to BAU at the other. Between those two limits lies a continuum of points/levels at which GHG emissions are mitigated and atmospheric concentrations of CO₂ are stabilized. The precise relations between GHG emissions, atmospheric

9. Put differently, "[a]n IAM is essentially a model of economic growth with a controllable externality of endogenous greenhouse warming." Martin Weitzman, *Structural Uncertainty and the Value of Statistical Life in the Economics of Catastrophic Climate Change* 28 (Nat'l Bureau of Econ. Research, Working Paper No. 13490, 2007), available at <http://papers.nber.org/papers/w13490>.

10. "PAGE" stands for "Policy Analysis of the Greenhouse Effect." See STERN, *supra* note 2, at 173; Chris Hope, *The Marginal Impact of CO₂ from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern*, 6 INTEGRATED ASSESSMENT J. 19 (2006), available at http://journals.sfu.ca/int_assess/index.php/iaj/article/view/227.

11. The failure to discuss all relevant details of the model, itself, can be considered a possible violation of "best practices" for BCA, especially given the overall importance of the choice of model to the outcome of the BCA. However, all relevant details about the model are available in Hope, *supra* note 10, on which this summary of the *Stern Review* relies extensively.

concentration levels, climate changes, and the human-health and socio-economic effects of those changes are, of course, subject to high levels of uncertainty, which increase with time. Among other uncertainties is the prospect of a nonlinear damage function resulting from extreme climate events, climate feedback mechanisms, and other large-scale discontinuities.¹² The Intergovernmental Panel on Climate Change's (IPCC) Third Assessment Report (TAR) had previously expressed serious concern over such impacts;¹³ Hope designed PAGE2002 precisely to incorporate them.¹⁴

The PAGE2002 IAM factors uncertainty into the analysis by incorporating a Monte Carlo analysis that repeatedly solves the model using 79 random variables for key parameters.¹⁵ Those variables include (among others) emissions of primary GHGs, atmospheric concentrations of GHGs, concentrations of sulfate aerosols that cool the atmosphere, regional temperature effects for eight regions of the world, nonlinear and transient damages, regional economic growth, investments in climate change adaptation measures, and the possibility of some future, large-scale discontinuity.¹⁶ The model is run 1000 times to generate "a range of possible trajectories for GDP per capita net of climate change related damage costs."¹⁷ It then produces a probability density function of damage outcomes for various GHG emission levels over time.¹⁸

It was precisely this ability of the PAGE2002 IAM to incorporate nonlinear damage functions, including potential catastrophic events, and nonmarket costs that evidently led the *Stern Review's* authors to adopt that model rather than alternative IAMs.¹⁹ Various statements throughout the

12. The term "discontinuity" in this context refers to a dramatic, non-linear increase in the damage function resulting from a potentially catastrophic event, such as the collapse of the West-Antarctic ice sheet. Richard Posner defines a "catastrophe" as "harm so great and sudden as to seem discontinuous with the flow of events that preceded it." RICHARD A. POSNER, *CATASTROPHE* 6 (2004).

13. See INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *CLIMATE CHANGE 2001, IPCC THIRD ASSESSMENT REPORT, IMPACTS, ADAPTION AND VULNERABILITY* (2001) [hereinafter IPCC THIRD ASSESSMENT REPORT].

14. Hope, *supra* note 10, at 20.

15. *Id.* at 36–37, app. I.

16. *Id.* at 20–21.

17. Maddison, *supra* note 5, at 4.

18. In simple terms, a "probability density function" is normally (but not always) a bell-shaped curve that describes the various probabilities of occurrence (or non-occurrence), which must sum to 1 (or 100 percent). For a more accurate but technical definition, see, for example, MERRAN EVANS ET AL., *STATISTICAL DISTRIBUTIONS* 9–11 (3d ed. 2000).

19. In contrast to PAGE2002, the IAM used by Mendelsohn et al. does not account for non-market impacts or catastrophic events. Mendelsohn et al., *supra* note 3, at 567. However, contrary to assertions made by STERN, *supra* note 2, at 171, fig. 6.3, other available models seem quite similar to PAGE2002. See, e.g., Richard S.J. Tol, *Estimates of the Costs of Climate Change – Part II: Dynamic Estimates*, 33 *ENERGY POL'Y* 2064 (2002); NORDHAUS & BOYER, *supra* note 3.

Stern Review signal an intention to estimate not only the mean expected-values of climate change damage, but higher harm-based scenarios as well. For example, Stern and his colleagues write that "the science and economics are particularly sparse precisely where the stakes are highest—at the high temperatures we now know may be possible."²⁰ Later, they state that "the knowledge base on which the cost of climate change is calibrated—specialized studies on impacts on agriculture, ecosystems and so on—is particularly patchy at high temperatures. In principle, the gaps that remain may lead to underestimates or overestimates of global impacts. In practice, however, most of the unresolved issues will increase damage estimates."²¹ The *Stern Review* then criticizes earlier studies for limiting their analyses "to a small subset of the most well understood, but least damaging, impacts."²² In effect, earlier analysts looked only where the light was better, ignoring impacts "that have the potential to inflict the greatest damage" simply because those impacts were "surrounded by the greatest scientific uncertainty."²³ Thus, the *Stern Review* seems to have been intended, at least in part, as a BCA of *worse-case* scenarios for climate change.²⁴

In addition to facilitating the incorporation of large-scale discontinuities in the damage function, PAGE2002 was consistent with the scientific projections of the IPCC's TAR, falling short by only about 40 ppm of CO₂ concentration at the IPCC's mean projection (under BAU) of 700 to 800 parts per million (ppm) for the year 2100. PAGE2002's fifth percentile and ninety-fifth percentile projections were also very close to the outer bounds of the IPCC's TAR projections.²⁵

Among the important projections of the IPCC's TAR, which profoundly influenced both the PAGE2002 IAM and the *Stern Review's* final assessment, was the finding that the impact of a large-scale discontinuity

20. STERN, *supra* note 2, at 34.

21. *Id.* at 149.

22. *Id.* at 150.

23. *Id.* at 151.

24. Weitzman, *supra* note 1, at 705, appears to agree with this assessment in noting that "the *Stern Review* consistently leans toward (and consistently phrases issues in terms of) assumptions and formulations that emphasize...pessimistically high expected damages from greenhouse warming—relative to most other studies of the economics of climate change." Whether or not the *Stern Review's* worse-case approach comports with (presumed) "best practices" in regulatory BCA is a question addressed later in this article.

25. It is worth wondering why the *Stern Review* was published just months before the IPCC released its *Fourth Assessment Report* (FAR) in 2007, which significantly altered some of the projections made in the 2001 TAR. The *Stern Review's* authors incorporated into their model a good deal of the science on which the FAR is based. However, they could not await the FAR's publication because they were operating under an autumn 2006 deadline set by the Chancellor of the Exchequer.

might exceed ordinary disasters by orders of magnitude.²⁶ The chance of large-scale discontinuities is estimated to be significant only after the mean temperature has risen 51°C over pre-industrial levels, but for every 11°C rise above that point, the chance of a large-scale discontinuity increases by ten percent.²⁷ PAGE2002 presumes that any discontinuous event would entail a ten percent loss to European Union gross domestic product (GDP). In recognition that other regions of the world would suffer greater or lesser losses (or even make gains) from higher-than-expected temperature changes, expected income affects are weighted to allow for comparison and aggregation across regions.²⁸

Because of the great uncertainties in the occurrence and effects of large-scale discontinuities, PAGE2002 provides wide parameter ranges. But as Hope and Stern both note,²⁹ it is important not to ignore large-scale discontinuities in estimating the economic effects of climate change just because they are subject to great uncertainty. Their intuition seems right: it is better to incorporate wide parameter ranges with high margins of error than to virtually ensure large errors by summarily excluding large-scale discontinuities from the damage function.³⁰

B. Applying the Model

1. *Estimating the Size and Distribution of Climate Change Cost*

The Stern group ran the PAGE2002 model under two different assumed levels of climatic response to BAU (no controls on present or future emissions rates) (1) the “baseline” scenario designed to give outputs consistent with the IPCC’s Third Assessment Report and (2) a “high climate” scenario that adds the risk of nonlinear damages, resulting for example from natural feedbacks in the climate system. Obviously, the “high climate” scenario results in a higher probability of larger temperature changes and, consequently, higher expected social costs. According to Stern, “In the high scenario, global mean temperature rises to an average of nearly 4.3°C above pre-industrial levels by 2100, compared with an average of 3.9°C above pre-industrial levels in the baseline scenario.”³¹ And the temperature difference between the two scenarios increases after 2100. By 2200, the average increase in mean global temperatures increases by 7.4°C

26. An “order of magnitude” is a scaled comparison of (sometimes approximate) amounts using a fixed ratio. So, for example, 10^2 (100) is one order of magnitude greater than 10^1 (10); 10^3 (1000) is two orders of magnitude greater than 10^1 (10).

27. IPCC THIRD ASSESSMENT REPORT, *supra* note 13, at 947.

28. Hope, *supra* note 10, at 23–24.

29. *Id.* at 25; STERN, *supra* note 2, at 170.

30. As we shall see later, Weitzman seems to agree.

31. STERN, *supra* note 2, at 158.

above pre-industrial levels on the baseline scenario, and by 8.6°C on the "high climate" scenario.³² The *Stern Review* warns that temperature increases, especially beyond the year 2100, should be treated as "indicative" only because uncertainty about effects increases with time.³³ But the *Review's* authors ignore their own words of caution in deriving preliminary estimates of average losses in global per capita GDP in 2200 ranging from 5.3 percent to 13.8 percent, "depending on the size of climate-system feedbacks and what estimates of 'non-market impacts' are included."³⁴ They do, however, add the important caveat that "growth in GDP will have made the world considerably richer than it is now."³⁵ This is significant because a certain percentage reduction in GDP will hurt a relatively poor country more than a relatively rich one. A five percent loss to a \$1 trillion economy is greater in nominal terms than a similar percentage loss to a \$1 billion economy; but the effect on the \$1 billion economy is likely to be more significant.

The size of climate change costs is not the only important consideration. The distribution of those costs also matters. The Stern group notes, in accordance with virtually every other analyst,³⁶ that the costs of climate change will not be distributed evenly or randomly throughout the world. Rather, the costs are expected to fall most heavily in less developed regions of the world that, until now, have contributed least to GHG emissions and can least afford to bear the costs of climate change. "[I]n the baseline-climate scenario with all three categories of economic impact [market, risk of catastrophe, and non-market], the mean cost to India and South-East Asia is around 6 percent of regional GDP by 2100, compared with a global average of 2.6 percent."³⁷ The inequitable distribution of climate change costs introduces an important ethical component into climate change policy, which the *Stern Review* does not neglect.

2. The Choice of Parameter Values

In deriving its damage figures, the *Stern Review* employs standard economic assumptions from welfare economics theory, including the assumption of diminishing marginal utility of income in evaluating risks and future welfare. But then Stern deliberately courts controversy by choosing a very low pure rate of time preference (utility discount rate) of 0.1

32. *Id.* at 157-159.

33. *Id.*

34. *Id.* at 153.

35. *Id.* at 155.

36. See, e.g., Thomas C. Schelling, *What Makes Greenhouse Sense?*, in T.C. SCHELLING, STRATEGIES OF COMMITMENT AND OTHER ESSAYS 34-35 (2006).

37. STERN, *supra* note 2, at 179.

percent per year.³⁸ A discussion of the controversy over that very low rate is postponed until the next section. For present purposes it is important to understanding the proper role the utility discount rate plays in the *Stern Review's* calculations. In particular, we need to distinguish carefully between pure rate of time preference and the interest rate used to discount consumption.³⁹

In Frank Ramsey's modern formulation of Irving Fisher's dynamic general equilibrium model of the interaction of preferences and technological change,

$$r = \rho + \eta g,$$

where r is the interest rate that discounts consumption, ρ is the pure rate of time preference, η is the elasticity of marginal utility or the base-case coefficient of relative risk aversion (a measure of what someone would be willing to pay today to insure against an expected future loss),⁴⁰ and g is the per-capita growth rate of consumption.⁴¹ In the *Stern Review*, $\rho = 0.1\%$, $\eta = 1$, and $g = 1.3\%$. Plugging these figures into the Ramsey equation gives us a value of r (the discount rate of consumption) = 1.4%. The choice of low values for ρ and η inevitably results in a low r . The *Stern Review's* $r = 1.4\%$ leads to estimated damage costs 100 years from now that exceed by two orders of magnitude estimates using $r = 6\%$ (e.g., where ρ , η , and g each = 2%).⁴²

Based on its preferred parameter values, the *Stern Review's* analysis shows that under BAU (uncontrolled GHG emissions indefinitely into the future) the risks of climate change between 2100 and 2200 will be equivalent to about five percent of the gross global product each year, and possibly as

38. Virtually everyone would rather receive a dollar today than a dollar tomorrow or five years from now. A dollar in hand today can be invested at some positive rate of interest so that it will be worth more than a dollar tomorrow and worth much more than a dollar five years from now. The "pure rate of time preference" or "utility discount rate" is an estimate of the interest rate at which individuals discount the value of money over time.

39. See Weitzman, *supra* note 1, at 706.

40. Quiggin, *supra* note 6 (explaining the effect of the choice of η (eta): "Using eta = 1, a sacrifice of \$70 per person (1 percent of income) today would be justified only if it increased the income of our great-grandchildren in 2100 by at least \$1,000. If this trade-off appears reasonable, then a value of eta = 1 is appropriate. If the future payoff required is higher (or lower) then so is the preferred value of eta.").

41. Weitzman, *supra* note 1, at 706.

42. *Id.* at 708. Weitzman rightly notes that this "no frills stripped-down variant of the Ramsey model... is liable to a thousand and one legitimate questions and criticisms about its oversimplifications, but at the end of the day... this exercise is highlighting fairly what really counts in the economics of climate change." *Id.* For a clear and accessible discussion of alternative models for discounting and the various issues they raise, see also Mark A. Moore et al., *Just Give Me a Number! Practical Values for the Social Discount Rate*, 23 J. POL'Y ANALYSIS & MGMT. 789 (2004).

high as 20 percent, "forever."⁴³ As noted earlier, estimated damages would be only one one-hundredth as large with different parameter values yielding $r = 6$ percent. This is not to say, however, that the *Stern Review's* parameter values were "wrong" or that its damage estimate is "too high." As the article later discusses, such conclusions involve ethical value judgments, which are inherently contestable.

3. *Assessing the Costs and Benefits of Carbon Mitigation/Climate Stabilization*

Next, the *Stern Review* authors assess the economics of mitigation/stabilization. In accordance with IPCC TAR and more recent data, they find that stabilizing GHG concentrations at levels that would avoid very costly climate changes will require "deep emissions cuts of at least 25 percent by 2050,"⁴⁴ implying a nominal decline of 30 to 35 GtCO₂.⁴⁵ To achieve that goal, emissions would peak during the next 10 to 20 years and then decline by between one percent and three percent per year.⁴⁶ The *Stern Review* estimates that cutting emissions 25 percent by 2050 would cost approximately one percent of annual global GDP (about \$1 trillion in 2050), plus or minus three percent, and would stabilize concentration levels at between 500 to 550 ppm of carbon dioxide equivalent (CO₂eq).⁴⁷ At concentration levels in that range, the most harmful effects of climate change would be averted. Stern calculates that by investing one percent of annual global GDP starting now and continuing potentially forever, the world could avert costs to annual global GDP of ten percent "forever."⁴⁸ In the "worst case," climate change mitigation would yield net costs amounting to 3.4 percent of annual global GDP. In the "best case," climate change mitigation would add 3.9 percent net to annual global GDP.⁴⁹

Finally, the *Stern Review* considers policy options for mitigating GHG emissions and recommends a Pigovian carbon tax or tradable permitting system to establish a price of carbon at or near the social-cost level.⁵⁰ Although the *Stern Review* presents a fairly comprehensive and detailed introduction to various policy options, it does not actually engage in a comparative BCA (or comparative cost-effectiveness analysis) of

43. STERN, *supra* note 2, at 186–87.

44. *Id.* at 191.

45. *Id.* at 227.

46. *Id.*

47. *Id.* at 191, 268.

48. *Id.* at 320.

49. *Id.* at 271.

50. *Id.* at xvii–xviii. A carbon tax would establish an explicit price, while a tradable permitting system would establish an implicit price by setting quantitative limits on carbon emissions. See generally Martin Weitzman, *Prices vs. Quantities*, 41 REV. ECON. STUD. 477 (1974).

alternative policies for achieving its goal of climate stabilization at 500 to 550 ppm of CO₂eq by 2050.

III. CRITIQUES OF THE STERN REVIEW

Turning now to the critics of the *Stern Review*, I will focus only on those criticisms with salience for the theory and practice of regulatory BCA. This is not the place, and I certainly do not possess the scientific expertise, to assess or resolve complaints that the *Review's* authors misinterpreted or misapplied scientific data.⁵¹ I assume that any set of "best practice" standards for BCA requires the use of the best available information inputs with due care to avoid errors,⁵² and that the Stern group made good-faith efforts to comply with that requirement.⁵³ If good-faith errors of scientific fact were made, then the authors certainly should correct them in a supplemental BCA. I further assume that any discrepancies between the science basis of the *Stern Review* and the IPCC's *Fourth Assessment Report*⁵⁴ will be resolved in a supplemental BCA, prepared under auspices of HM Treasury, using the same PAGE2002 IAM or explaining why new data require a change in the model. Having cabined scientific/factual errors and subsequent improvements to the knowledge base, we can proceed to address what is truly significant in the *Stern Review* for the theory and practice of regulatory BCA.

Relevant critiques of the *Stern Review* focus on its damage estimates and parameter valuations, including the pure rate of time preference (ρ), the value of (η), and the rate of growth in per capita consumption (g).

51. See, e.g., Robert M. Carter et al., *The Stern Review: A Dual Critique: Part I: The Science*, 7 WORLD ECON. 167 (2006), available at <http://meteo.lcd.lu/globalwarming/Carter/WE-STERN.pdf>.

52. It is, perhaps, the first "best practice" standard of regulatory BCA to exercise due care in avoiding the problem of "garbage in, garbage out."

53. Yohe & Tol, *supra* note 5, at 39, allege that the *Stern Review* "subjected academic standards to political goals." Similarly, Nordhaus, *supra* note 5, at 688, suggests that "the *Review* should be read primarily as a document [that] is political in nature and has advocacy as its purpose." Such statements fall short, however, of alleging deliberate manipulation of inputs or procedures. Neither Nordhaus nor Yohe and Tol provide any evidence of deliberate manipulation. The use of a low pure rate of time preference is not necessarily evidence that the *Stern Review* authors were massaging the numbers to yield an outcome they preferred. Even if we disagree with $\rho = 0.1$ percent, the *Stern Review* sets forth legitimate reasons (aside from instrumental political values) to support that value.

54. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, FOURTH ASSESSMENT REPORT (2007) [hereinafter IPCC FOURTH ASSESSMENT REPORT].

A. Problems with the *Stern Review's* Damage Estimates

Yohe and Tol provide several "reasons for concern" about the *Stern Review's* damage estimates, including the fact that they exceeded other studies' damage estimates by three standard deviations.⁵⁵ In part, this is a function of Stern's assumption of more pessimistic scenarios. Mendelsohn also points out that Stern assumed large nonmarket damages, without supporting evidence.⁵⁶ Sterner and Persson, by contrast, argue that the *Stern Review's* PAGE2002 IAM and all other climate change IAMs systematically underestimate nonmarket damages.⁵⁷ Most problematically, Stern did not specify assumed valuations for human lives and other nonmarket goods, rendering the *Review's* damage estimations impossible to assess or replicate. This omission must violate any conceivable set of "best practice" standards for BCA.

B. Is $\rho = 0.1\%$ Too Low?

The single most controversial aspect of the *Stern Review* undoubtedly has been the choice of 0.1 percent as the pure rate of time preference (ρ). The reason, of course, is that this choice significantly affects the overall outcome of the BCA. As noted earlier, the *Stern Review's* unusually low ρ , when combined with an unusually low coefficient of relative risk aversion ($\eta = 1$), yields an unusually low interest rate ($r = 1.4\%$) for discounting future consumption, which magnifies future damages by two orders of magnitude over a more traditional six-percent interest rate for discounting future consumption.⁵⁸ As Yohe and Tol observe,

Moving from a discount rate of 0.1 percent to 1 percent would lower damage estimates by nearly 60 percent; moving to 2 percent by roughly another 20 percent, and moving to 3 percent by another 15 percent. As a result, damages calculated from the same underlying data with a 3 percent

55. Yohe & Tol, *supra* note 5, at 40, tbl. 1. Statisticians use the concept of "standard deviation" to describe the extent to which data points in a probability distribution are dispersed around the mean. In other words, it is a measure of variance. A higher standard deviation (e.g., three instead of one) implies a greater variance from the mean.

56. Mendelsohn et al., *supra* note 5, at 44. It is worth noting that Mendelsohn's own models of climate change exclude nonmarket damages altogether.

57. Sterner & Persson, *supra* note 6. However, Sterner and Persson assume that climate impacts have a positive income elasticity, whereas studies show that poorer people tend to be more vulnerable to climate change effects. See, e.g., Robert Mendelsohn et al., *The Distributional Impact of Climate Change on Rich and Poor Countries*, 11 ENV'T & DEV. ECON. 159 (2006). I am grateful to Richard Tol for pointing out this aspect of Sterner and Persson's analysis.

58. This is not to endorse six percent as an appropriate value of r but merely to demonstrate the sensitivity of damage estimates to the consumption discount rate.

discount rate would produce damage estimates between 10 and 20 percent of the estimates reported in the *Review*.⁵⁹

Compared to other studies, the *Stern Review*'s discount rate is indeed very low, and its estimate of damages correspondingly high. Tol analyzed 28 published studies that provided 103 total estimates of the marginal damage costs of carbon dioxide emissions.⁶⁰ The utility discount rates in those 28 studies generally ranged between one and three percent (with some cases of hyperbolic discounting). Tol's comparison found that the utility discount rate/pure rate of time preference starkly influences both the central estimate and the uncertainty:

If we use a pure rate of time preference of 3 percent — corresponding to a social rate of discount of 4–5 percent, close to what most western governments use for most long-term investments — the combined mean estimate is \$16/tC (ton of carbon), not exceeding \$62/tC with a probability of 95 percent. Lower social rates of discount lead to higher estimates but particularly to greater uncertainty, but even for a 1 percent pure rate of time preference the combined mean is \$51/tC. Even lower discount rates may be morally preferable, but are clearly out of line with common practice.⁶¹

That last sentence is intriguing. If lower discount rates are “morally preferable” but “out of line with common practice,” as Tol suggests they might be, which should be adjusted, the “morally preferable” discount rate or the “common practice”? As we shall see later, Weitzman presents a strong ethical argument that the discount rate should be made to comport to convention.⁶² But Weitzman also notes that structural uncertainties in climate change damage estimates might justify the selection of a very low discount rate (although he would prefer to deal with such structural uncertainties via the damage function, rather than the discount rate).⁶³

The *Stern Review*'s estimate of \$85/tCO₂eq under BAU exceeded by more than a factor of five Tol's combined mean estimate from 28 previous studies.⁶⁴ No wonder the *Stern Review* calls for quicker and steeper reductions in GHG emissions than any previous BCA. This is not to say,

59. Yohe & Tol, *supra* note 5, at 39–40.

60. Richard S.J. Tol, *The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties*, 33 ENERGY POL'Y 2064 (2005).

61. *Id.* at 2073.

62. Weitzman, *supra* note 1.

63. *See id.* at 713–14.

64. Compare Stern, *supra* note 2, at 322, and Tol, *supra* note 60. The term “tCO₂eq” stands for ton of carbon dioxide equivalent. It represents a means by which emissions of various greenhouse gases, which have differential effects, can be commonly evaluated.

however, that the *Stern Review's* cost-estimate is necessarily wrong. Tol concedes that

[t]he current generation of aggregate estimates may understate the true cost of climate change because they tend to ignore extreme weather events; exclude low probability/ high consequence scenarios, such as a shut-down of the thermohaline circulation...or a collapse of the West-Antarctic ice sheet...; underestimate the compounding effect of multiple stresses; and ignore the costs of transition and learning.⁶⁵

Each of the factors missing from the earlier generation of aggregate estimates is present and accounted for in the *Stern Review*. That must justify a higher cost-estimate. How much higher? Tol does not tell us, but concludes that the *Stern Review* "overestimates the impacts of climate change, and therefore the benefits of emission reduction."⁶⁶

William Nordhaus agrees with Tol's assessment and concludes that the *Stern Review's* choice of a very low ρ , more than any other factor, explains why the *Stern Review's* results differ so dramatically from those of other climate change BCAs, including his own.⁶⁷

The *Review* proposes ethical assumptions that produce very low discount rates. Combined with other assumptions, this magnifies impacts in the distant future and rationalizes deep cuts in emissions, and indeed in all consumption, today. If we substitute more conventional discount rates used in other

65. Tol, *supra* note 60, at 2067.

66. Tol, *supra* note 5, at 979. In the popular media, Tol was even more damning of the *Stern Review's* conclusions:

"If a student of mine were to hand in this report as a Master's thesis, perhaps if I were in a good mood I would give him a 'D' for diligence; but more likely I would give him an 'F' for fail....There is a whole range of very basic economics mistakes that somebody who claims to be a Professor of Economics simply should not make."

Quoted in Simon Cox & Richard Vadon, *Running the Rule over Stern's Numbers*, BBCNews, Jan. 26, 2007, available at <http://newsvote.bbc.co.uk/mpapps/pagetools/print/newsbbc.co.uk/2/hi/science/nature/6295021.stm>. Most recently, Tol, along with Gary Yohe and Dean Murphy, has taken a more generous approach to the *Stern Review*. After noting that "unusually harsh words have been said about the *Stern Review*" (including by both Tol and Yohe), they concede that "the *Review* may be right," albeit "for the wrong reasons." Gary Yohe et al., *On Setting Near-term Climate Policy While the Dust Begins to Settle: The Legacy of the Stern Review*, 18 ENERGY & ENV'T 621 (2007). Instead of berating Stern for shoddy economics, they treat the disagreements over discount rates, damage functions, etc. as technical details, which, while controversial among economists, should not deter policy makers from taking immediate action. *Id.* at 624.

67. Nordhaus, *supra* note 5.

global-warming analyses by governments, by consumers, or by businesses, the *Review's* dramatic results disappear....⁶⁸

Nordhaus is right that the *Stern Review's* damage estimates would be significantly lower under higher discount rates, but that does not necessarily imply that the discount rate alone drives the *Review's* conclusions and recommendations. Using Stern's damage estimates, Kenneth Arrow finds that the *Review's* "fundamental conclusion is justified ...even if...one heavily discounts the future."⁶⁹ In fact, Arrow calculates that present mitigation of GHG emissions is better than BAU "for any social rate of time preference (ρ) less than 8.5 percent," a rate higher than any analyst recommends.⁷⁰ Arrow concludes that "the case for intervention to keep CO₂ levels within bounds (say, aiming to stabilize them at about 550 ppm) is sufficiently strong as to be insensitive to the arguments about ρ ."⁷¹

Even if Nordhaus were right that Stern's unusually low utility discount rate completely determined the outcome of the economic analysis, it is important to recognize that Nordhaus, himself, has a dog in this hunt. He has been conducting economic analyses of climate change for more than three decades. In recent years, his analyses have utilized a 3-percent discount rate, declining to one percent per year over 300 years.⁷² The *Stern Review* expressly argues that Nordhaus's studies using the DICE IAM (and other analysts' studies using different IAMs) have systematically underestimated the costs of climate change under a BAU scenario.⁷³ By attacking the *Stern Review's* relatively low parameter values, Nordhaus is defending his own choices, which admittedly are more consistent with the rest of the literature (much of which has, of course, been influenced by Nordhaus's studies).⁷⁴

But why did the *Stern Review* authors choose such a low utility discount rate in the first place? Was their intent simply to manipulate cost

68. *Id.* at 689.

69. Arrow, *supra* note 6, at 1.

70. *Id.* at 5.

71. *Id.* at 4.

72. Nordhaus's newly minted DICE-2007 model uses a constant pure rate of time preference of 1.5 percent. For a more extensive description of DICE-2007, see *infra* note 142.

73. STERN, *supra* note 2, at 170–73. Other critics have made similar arguments about Nordhaus's model. See, e.g., William Cline, *Meeting the Challenge of Global Warming*, in GLOBAL CRISES, GLOBAL SOLUTIONS (Bjørn Lomborg ed., 2004); Frank Ackerman & Ian Finlayson, *The Economics of Inaction on Climate Change: A Critique* (Oct. 2005) (unpublished manuscript, available at http://www.hm-treasury.gov.uk/media/9/F/climatechange_tufts_2.pdf); Quiggin, *supra* note 6.

74. In an e-mail message sent to Sir Nicholas Stern, Nordhaus reportedly stated that the *Review* is "a great study, but it is 50 years ahead of its time....Since everybody else is 50 years behind the times, if you average the two, you might come out just right." David Leonhardt, *Amid the Ivy, A Battle About the Climate*, N.Y. TIMES, Feb. 21, 2007, at C1.

estimates so as to justify more rapid and extreme measures to control GHG emissions? The *Stern Review* is replete with expressions of concern that earlier studies had underestimated the costs of climate change, but the authors do not attempt to justify the choice of a low discount rate based on that concern alone. Rather, they follow the lead of several other prominent economists such as Frank Ramsey, Amartya Sen, and Robert Solow in presenting affirmative and legitimate *ethical reasons* against anything higher than a minimal discount rate for estimating the costs of climate change.⁷⁵ Ramsey famously argued that discounting is "ethically indefensible and arises merely from the weakness of the imagination."⁷⁶ The late David Pearce argued that discounting is a "brute fact" because people are *observed* to discount for time and space in making individual investment/consumption decisions.⁷⁷ But just because people are observed to do it does not make it right. Ramsey's point is that both the decision to discount and the choice of a social discount rate are not just matters of positive economics but normative ethics.⁷⁸ Stern agrees with Ramsey that people should not discount for time and space. Indeed, the only reason the *Stern Review* uses a 0.1 percent pure rate of time preference, rather than a zero rate, is the risk of human extinction during the course of the current century.⁷⁹

The bottom-line question for present purposes is whether the *Stern Review's* pure rate of time preference is so low as to violate some presumed "best practice" standard. As a matter of theory and practice, this is a difficult question to answer. The choice of a social discount rate is inherently subjective and as Portney and Weyant have observed, "Those looking for guidance on the choice of discount rate could find justification [in the literature] for a rate at or near zero, as high as 20 percent, and any and all values in between."⁸⁰ Thus, the *Stern Review's* choice of a discount rate close to zero does not seem invalid per se. That it deviates from the literature does not make it wrong, only deviant. We might conclude that

75. STERN, *supra* note 2, at 35–36.

76. Frank Ramsey, *A Mathematical Theory of Saving*, 38 ECON. J. 543 (1928). What Ramsey refers to as a "failure of imagination," Arrow et al. refer to as "impatience or myopia." Kenneth J. Arrow et al., *Intertemporal Equity and Discounting*, in GLOBAL CLIMATE CHANGE: ECONOMIC AND POLICY ISSUES 5 (M. Munasinghe ed., World Bank Environment Paper No. 12, 1995).

77. David Pearce et al., *Valuing the Future: Recent Advances in Social Discounting*, 4 WORLD ECON. 121, 122 (2003).

78. For a more extensive discussion of economic and philosophical arguments against discounting and their potential role in determining "best practices" for BCA, see Cole, *supra* note 8, at 30–31.

79. STERN, *supra* note 2, at 45. On the significance of the probability of human extinction for the choice of the social rate of discount, see Menachem E. Yarri, *A Law of Large Numbers in the Theory of Consumer's Choice Under Uncertainty*, 12 J. ECON. THEORY 202 (1976).

80. DISCOUNTING AND INTERGENERATIONAL EQUITY 1, 4 (Paul R. Portney & John P. Weyant eds., 1999).

deviance from an accepted norm would violate a duty of BCA producers not to impose their own values paternalistically on society.⁸¹ But it is not at all clear that such a norm (yet) exists.⁸² However, as we shall see in section III.C, there is a counter-argument to Stern's ethical claims about the discount rate.

C. Is $\eta = 1$ Too Low?

One prominent critic of the *Stern Review*, Partha Dasgupta, has no complaint with the choice of 0.1 percent for the pure rate of time preference;⁸³ he has previously suggested that the discount rate for climate change might be zero or even negative if costs are severe enough to require reductions in consumption.⁸⁴ Moreover, Dasgupta notes that there is precedent for Stern's choice of a low pure rate of time preference in William Cline's economic analysis of global warming,⁸⁵ which set ρ at zero.⁸⁶

However, Dasgupta is highly critical of the *Stern Review's* choice of η (the elasticity of marginal utility or coefficient of relative risk aversion). "To assume that $[\eta]$ equals 1 is to say that the distribution of well-being among people doesn't matter much, that we should spend huge amounts for later generations even if, adjusting for risk, they were expected to be much better off than us."⁸⁷ A high η would "imply greater sensitivity to risk and inequality in consumption."⁸⁸

81. Weitzman, *supra* note 1, at 709, 720 (making a similar point).

82. See Cole, *supra* note 8, at 27–32. Matthew Adler argues that "the presumption against paternalism that informs much economic writing should be no part of CBA [cost-benefit analysis]. CBA should neutrally assess the costs and benefits of paternalism, recognizing that paternalistic measures (like all government measures) have costs, but these costs might be outweighed by the benefits." Matthew Adler, *Cost-benefit Analysis: New Foundations*, LEGISLAÇÃO 42–43 (2006). See also MATTHEW D. ADLER & ERIC A. POSNER, *NEW FOUNDATIONS OF COST-BENEFIT ANALYSIS* (2006). Even assuming Adler is right about paternalism in BCA, however, it is not obviously the place of the economists who prepare economic analyses to impose their own subjective values in the process. We will return to this issue in the following section.

83. See Dasgupta, *supra* note 5.

84. Partha Dasgupta et al., *Intergenerational Equity, Social Discount Rates, and Global Warming*, in *DISCOUNTING AND INTERGENERATIONAL EQUITY*, *supra* note 80, at 51.

85. See CLINE, *supra* note 3. In fact, Cline adopted parameter values, all of which were very close to those chosen by Stern. In Cline, $\rho = 0\%$, $\eta = 1.5$, and $g = 1\%$, which in the Ramsey model yields $r = 1.5\%$, a mere one-tenth of one percent above the *Stern Review's* value for r . Weitzman, *supra* note 1, at 712, notes that Cline, like Stern, reached "strong activist conclusions."

86. Dasgupta, *supra* note 5, at 5.

87. *Id.* at 6.

88. *Id.* In addition to his critique of the *Stern Review's* choice of η , Dasgupta, *id.* at 6–7, makes an important observation about the public choice implications of the *Review's* conclusion that the world should spend one percent of global GDP annually to combat climate

To give a feel for how changing the η alters consequences, Dasgupta provides the following example. If the rate of return on investment is four percent per annum, then under the *Stern Review's* assumptions of $\rho = 0.1$ and $\eta = 1$ the social saving rate ought to be 97.5 percent, which is so out of line with social practice as to be ridiculous. If, however, we altered the *Stern Review's* assumptions so that η equaled three, the optimum saving rate would fall to a more reasonable (at least for wealthy countries) savings rate of 25 percent of net aggregate output. Dasgupta notes that the *Stern Review* contains no sensitivity analysis for its set of assumptions about the values of ρ , η , and g .⁸⁹ From the perspective of "best practices" for BCA, this is probably his most significant complaint.

John Quiggin takes issue with Dasgupta's argument about the *Stern Review's* valuation of η based on a presumed four-percent market rate of return on investment. According to Quiggin, "the fact that we see more rapid growth with lower rates of net saving seems to imply that there must exist many projects with rates of return greater than or equal to 4 percent." In addition, "[i]n an economy where most growth in consumption arises

change. He reasonably assumes that all of the spending would come from the world's developed countries, and that one percent of global GDP would equal 1.8 percent of developed countries' GDP. But, he notes, that figure would be "some seven times the annual global aid budget." Implicit is the assumption that spending to mitigate global climate change constitutes foreign aid. *Id.* This assumption is strongly supported by Tom Schelling's assessment of climate change as a political-economic issue. According to Schelling, *supra* note 36, spending to counteract climate change constitutes foreign aid because the primary (if not exclusive) "investors" would be developed countries, while the primary (though not exclusive) beneficiaries would be developing countries, which are expected to bear the brunt of climate change costs. *See also* Schelling, *supra* note 36, at 34-35. POSNER, *supra* note 12, at 125-26, 256, generally concurs in this assessment but suggests that spending to prevent abrupt climate change catastrophes would not constitute foreign aid because such catastrophes would impose huge costs on the developed world as well as the developing world.

To the extent that climate change investments *would* constitute foreign aid, a key question becomes how to persuade voting publics in developed countries "to instruct their governments, collectively," to increase foreign aid spending so dramatically in accordance with the recommendations of the *Stern Review*. Dasgupta, *supra* note 5, at 7. Dasgupta suggests that simply stating it as a moral imperative is unlikely to be effective. But, of course, the *Stern Review* does not simply make a moral argument about the need for more spending to minimize the social costs of climate change; its argument is first and foremost economic. If spending more now can reduce costs down the road (after those costs are discounted to present value), then the choice is a matter of both economic efficiency and ethics. Whether or not developed countries would internalize enough of those efficiency gains to make the additional investment in foreign aid worthwhile remains questionable. And so the public choice issue remains. But the same issues would remain with respect to *any* recommendation to mitigate greenhouse gas emissions. Meanwhile, the possibility of climate change catastrophes, referred to by Posner, should reduce political opposition to mitigation investments. As such, spending would not amount to foreign aid.

89. Dasgupta, *supra* note 5, at 6.

from technical progress, the optimal rate of saving is far lower than that derived by Dasgupta." Finally,

[a] more direct way of refuting Dasgupta's argument is to observe that the major premise must be false. If there existed an infinite supply of projects with riskless returns of 4 per cent, the rate of return on riskless bonds would have to equal 4 percent, rather than the 1 to 2 percent observed in practice.⁹⁰

Whether or not we agree with Dasgupta that the *Stern Review's* η is too low, he has performed a valuable service in focusing attention on a relatively neglected element in the composition of r (the discount rate of consumption). The η actually combines three distinct valuations within a single number: (1) a measure of risk aversion, (2) a judgment about the extent of static income inequality among different people, and (3) a judgment about the extent of dynamic income inequality for individuals over time. The inferences we make about each one of these judgments affects the valuations of the others and the overall valuation of η .⁹¹ According to Weitzman's interpretation, the authors of the *Stern Review* seem to want a low η for some purposes, but a higher η for others.⁹² Utilizing inconsistent values of η would seem to violate best practices in BCA, but the temptation to assign inconsistent values to η is understandable given the variety of potentially inconsistent judgments that η incorporates.

Finally, arguing that the *Stern Review's* value of η is either too high or too low seems myopic because the η is only one element in the Ramsey equation's formula for determining the social rate of discount. A low or high value of η does not by itself tell us anything about the values of future costs and benefits of climate change and GHG mitigation. As Sterner and Persson note, "A higher value of η implies less greenhouse gas abatement today unless we will not be richer but poorer in the future: then the logic implies that a higher η gives higher damage values, and more abatement would be warranted."⁹³ To see how a higher value of η could result in a policy of more present investment in abatement of GHG emissions, assume that $\rho = 3$, $g = -1$, and $\eta = 3$. Plugging those elements into the Ramsey equation yields $r = 0$. While some economists might scoff at the notion of a negative rate of growth in consumption, we shall see shortly that climate

90. Quiggin, *supra* note 6, at 15.

91. I am grateful to Marty Weitzman for his assistance in unpacking these discrete aspects of the η and the complications that can (but do not necessarily) arise from their combination into a single numeric value.

92. Weitzman, *supra* note 1.

93. Sterner & Persson, *supra* note 6, at 6.

models forecast a low but positive probability of extreme changes that could result in what Weitzman calls "low- g disasters."⁹⁴

D. It's the r , Stupid!

As a practical matter, neither the choice of ρ (pure rate of time preference) nor η (coefficient of the relative rate of risk aversion), alone, is critical. Rather, it is the combination of those factors along with g (the assumed growth rate of per capita consumption) in the Ramsey equation that determine r (the interest rate at which future consumption is discounted).⁹⁵ As noted above, the *Stern Review* selects the following values: $\rho = 0.1\%$, $\eta = 1$, and $g = 1.3\%$ to yield $r = 1.4\%$. Weitzman agrees with Nordhaus and Tol that "[t]he discount rate we choose is all important and *Stern's* results come from choosing a very low discount rate...."⁹⁶ But whereas Nordhaus and Tol focused on the ρ , Weitzman more appropriately focuses on the r . He notes that if $\rho = 2\%$, $\eta = 2$, and $g = 2\%$, then $r = 6\%$. If we assume instead that $\rho = 0\%$, $\eta = 3$, and $g = 2\%$, then r is still $= 6\%$. Thus, we can derive the same consumption discount rate, whether ρ equals two percent or zero percent, by adjusting the η and/or g .⁹⁷ Likewise, the same social discount rate can be attained regardless of the value of η by adjusting the ρ or the g .

The *Stern Review's* valuation of $r = 1.4\%$ is comparatively low because $\rho = 0.1\%$ and the value chosen for the coefficient of the relative rate of risk aversion, $\eta = 1$, is "the lowest lower bound of just about any economist's best-guess range."⁹⁸ Weitzman points out that under an alternative $r = 6$ (which Weitzman does not necessarily recommend as correct or preferable), the *Stern Review's* present discounted value of damages from climate change over the next 100 years would be lower by two orders of magnitude. And so, "what really counts in the economics of climate change [is] the hidden discounting assumptions whose role tends to be more obscured than informed by the big IAMs."⁹⁹ This is not just a

94. Weitzman, *supra* note 1, at 717.

95. See STERN, *supra* note 2, at 52-54; Weitzman, *supra* note 1, at 707.

96. Weitzman, *supra* note 1, at 704. He does not argue, however, that Stern was wrong to adopt such a low pure rate of time preference but only notes that "*Stern* follows a decidedly-minority paternalistic view (which, however, includes a handful of distinguished economists)." *Id.* at 707.

97. *Id.* at 707.

98. *Id.*

99. *Id.* at 708. It is not at all clear why Weitzman believes that the discounting assumptions in Stern or other models have been "hidden." They are debatable to be sure, and they may drive the outcomes of the *Stern Review* and every other economic analysis of climate change. However, Stern is certainly explicit about the choice of discounting assumptions and provides explicit arguments in support of its assumptions. *Id.*

criticism of the *Stern Review* and its choice of parameter values but a challenge to the entire practice of economic analysis of climate change. It has special relevance for the *Stern Review*, however, simply because the *Review's* authors assumed parameter values that ignored how people are observed to act. As Weitzman puts it,

Stern's worldview tends to blow off market-based observations and behavioral inferences as being (for a variety of reasons including market incompleteness) largely irrelevant to long-run discounting, which should instead be based primarily upon the "ethical" value $\delta \approx 0$ that *Stern* imposes on *a priori* grounds....While there may be *something* to *Stern's* position about the limited relevance of market-based inferences for putting welfare weights on the utilities of one's great-grandchildren, and there might be *some* sporadic support for *Stern's* preferred taste parameters scattered throughout the literature, I ultimately find such an extreme stance on the primacy of $\delta \approx 0$, $\eta \approx 1$ unconvincing when super-strong policy advice is so dependent upon non-conventional assumptions that go so strongly against mainstream economics.¹⁰⁰

In essence, Weitzman's argument is about the values of convention and prudence in BCA. In his view, analysts should not rest strong and socially costly policy recommendations on conclusions resulting from unconventional assumptions that run counter to observed economic behavior.¹⁰¹ In addition, Weitzman seems to be making an important point about the

100. *Id.* at 709. Later in his review, however, Weitzman shows that observed economic behavior creates problems not just for Stern's choice of parameter values but "threatens all such formulations." *Id.* at 714.

101. *Id.* at 704–05. However, as Newell and Pizer point out, "there are few if any observable market rates for investment horizons more than 30 years in the future, making the interest rate beyond those horizons even more uncertain than it otherwise might be." RICHARD NEWELL & WILLIAM PIZER, DISCOUNTING THE BENEFITS OF CLIMATE CHANGE MITIGATION: HOW MUCH DO UNCERTAIN RATES INCREASE VALUATIONS? 13 (Pew Center on Global Climate Change 2001), available at <http://www.rff.org/RFF/Documents/RFF-RPT-disbenefits.pdf>. Given the lack of "observable market rates" for investments with longer time horizons and the likelihood that uncertainty over future interest rates militates in favor of lower discount rates, to what extent can the *Stern Review* really be faulted for ignoring "observed economic behavior" in selecting a value of ρ ? Weitzman, *supra* note 1, at 714. Even if we could observe market rates for investments with very long time horizons, Sterner & Persson, *supra* note 6, at 5, argue that "using an observable real market variable as a benchmark is not appropriate because we are searching for a number on which to base ethical or normative judgments. We are not simply observing the market as we do in positive or empirical studies; rather, we are providing arguments for public action that involves the provision of very complex public goods." Quoting Hume, they go on to note that "one cannot derive an *ought* from an *is*." *Id.* at 6. Obviously, Sterner and Persson have a different view than Weitzman of the role of BCA.

role of economic analysts: their job is not to impose their own values and preferences on society but to input the best available data in a responsible fashion and analyze that data using models based on prudent assumptions that are broadly consistent with the way people are actually observed to behave. Then, they can present the results to policy makers, whose job it is to make decisions that either comport with or "go so strongly against mainstream economics."¹⁰² If I am interpreting him correctly, Weitzman is making a strong ethical argument about the propriety of social discounting and, more generally, about how BCAs should and should not be done.

E. Or, Is It the *g* (Specifically, "Low-*g*" Catastrophes)?

Although Weitzman strongly criticizes the *Stern Review* for its assumptions and analytical weaknesses, he is not as quick as other reviewers to denounce its conclusions or policy recommendations. To the contrary, he suggests that the *Stern Review's* value of *r* "may end up being more right than wrong when full accounting is made for the uncertainty of the discount rate itself, which arguably is the most important uncertainty of all in the economics of climate change"¹⁰³ Why?

The very same force of compound interest that makes costs and benefits a century from now seem relatively insignificant, and that additionally creates the "majority tilt" of a pain-postponing climate policy ramp of emissions reductions starting from a low gradual base [as in Nordhaus's model], also forces us to recognize the logic that over such long periods we should be using interest rates at the lower end of the spectrum of possible values.¹⁰⁴

Specifically, Weitzman suggests that uncertainty over which discount rates to use for the costs and benefits of climate change a century from now might reduce the value of *r* from six percent to as low as two percent, which is not far above the *Stern Review's* value of *r*.¹⁰⁵

Because Weitzman does not agree with the *Stern Review's* use of the discount rate to deal with the problem of possible extreme climate events ("low-*g* catastrophes"), he develops a new model that factors structural uncertainty into the Ramsey equation. I will not reproduce his formal model

102. Weitzman, *supra* note 1, at 709. The roles of analyst and policy maker are somewhat obscured in the *Stern Review* because, in his position as second permanent secretary of HM Treasury, Sir Nicholas Stern was not *just* an analyst but a policy maker as well.

103. *Id.* at 710. See also Arrow et al., *supra* note 76, at 5, n.6 (noting that the issue of how to deal with uncertainty in forecasting is "[n]ot yet resolved").

104. Weitzman, *supra* note 1, at 710.

105. *Id.* at 723.

here, but his argument boils down to this: the comparatively low parameter values assumed by Stern¹⁰⁶ and Cline¹⁰⁷ may well be justified because the damages of climate change over the next century might not coordinate well with aggregate economic activity. The economic sectors most likely to be harmed by climate change, such as agricultural, outdoor recreation, and natural landscapes (including nonmarket ecosystem values) are not “highly correlated with technological progress in computer power, furniture making, or better pharmaceuticals a century from now.”¹⁰⁸ This presents a big problem for those who favor basing the discount rate on the economy-wide return on capital. The other option is to base the discount rate on the risk-free rate of return, which “is close to the *Stern* interest rate.”¹⁰⁹

The “moral” drawn by Weitzman “is that the nature of the impacts of climate change determine[s] whether we should end up closer to using the risk-free rate or the economy-wide return on capital.” But “trying to forecast costs and benefits of climate change scenarios a hundred years or so from now is more the art of inspired guesstimating by analogy than a science (imagine forecasting today’s world a century ago).”¹¹⁰ Is Weitzman suggesting that “state of the art” economic analysis is not yet up to the task of dealing with a problem as potentially large and long-term as climate change? The last three sections of Weitzman’s review of the *Stern Review* suggest that the answer to this question is a qualified yes.

The problem, in a nutshell, is the wide range of possible temperature increases under the IPCC’s most current climate change models,¹¹¹ including a five-percent possibility that temperature increases will equal or exceed 6°C and a two-percent probability of increases equal to or greater than 8°C within the next 100 to 200 years.¹¹² Weitzman notes that “any honest economic modeler would have to admit” to complete uncertainty about the social, economic, and environmental effects of such a temperature increase because “such high temperatures have not existed for some tens of millions of years.”¹¹³ Even if their probability is low, high temperature increases and their climatic consequences, the kind of worse-case scenarios that the *Stern Review* emphasized, could result in what Weitzman calls “low-g disasters” (especially if *g* is defined, as Weitzman defines it, to include the existence value of ecosystems).¹¹⁴ The possibility of

106. STERN, *supra* note 2.

107. CLINE, *supra* note 3.

108. Weitzman, *supra* note 1, at 713.

109. *Id.* at 714.

110. *Id.* at 715. Schelling, *supra* note 36, at 33–34 (making a similar point).

111. See IPCC FOURTH ASSESSMENT REPORT, *supra* note 54.

112. Weitzman, *supra* note 9, at 2.

113. Weitzman, *supra* note 1, at 716.

114. *Id.* at 717.

such disasters makes prediction "uncertain" in the Knightian sense of the term.¹¹⁵ As Weitzman explains, "With an evolutionary stochastic process like global climate change, the world is not standing still long enough for us to accumulate the relevant information to accurately assess tail probabilities."¹¹⁶ We don't even know how much we don't know about the probabilities. The structural uncertainties, Weitzman notes, are highly likely to matter more than the risk for "whomever wants to model optimal-expected-utility growth under endogenous greenhouse warming."

Weitzman commends the *Stern Review* for treating seriously the possibility of rare, high-temperature, "low- g " catastrophes, but thinks that Stern should have dealt with such catastrophes forthrightly rather than "through the back door" with unreasonably low values of ρ and η .¹¹⁷ Presumably, this means that damage estimates should be increased or the value of g should be lowered based on some admittedly error-prone calculation of the anticipated effects of high-temperature changes on consumption levels. But Weitzman also doubts the ability of Stern or any other economic analyst to perform such calculations given the current state of economic science. And like other reviewers, he faults the *Stern Review* "for giving readers an authoritative-looking impression that seemingly objective best-available-practice professional economic analysis robustly supports its conclusions...."¹¹⁸ Weitzman suggests that the *Review* should have instead "more openly disclos[ed] the full extent to which the *Review's* radical policy recommendations depend on controversial extreme assumptions and unconventional discount rates that most mainstream economists would consider much too low."¹¹⁹

Finally, Weitzman urges caution in approaching these kinds of problems in economic analyses: "A responsible policy approach neither dismisses the horror stories just because they are two standard deviations away from what is likely nor gets stampeded into overemphasizing false dichotomies as if we must make costly all-or-nothing investment decisions right now to avoid theoretically possible horrible outcomes in the distant future."¹²⁰ Thus, he recommends a "middle course" that rejects the *Stern*

115. See FRANK KNIGHT, *RISK, UNCERTAINTY, AND PROFIT* (1921) (distinguishing between "risks" to which probabilities can be attached and "uncertainties" to which probabilities cannot be attached).

116. Weitzman, *supra* note 1, at 717.

117. *Id.* at 720. This assertion appears to impute bad faith to the *Stern Review* authors. But, as noted earlier, they specified ostensibly legitimate reasons for their choices of parameter values. Moreover, it is not clear why Weitzman considers it illegitimate to account for low-probability, high-magnitude climate events by adjusting parameter values. *Id.*

118. *Id.* at 724.

119. *Id.*

120. *Id.* at 722.

Review's call for an "all-out war" on GHG emissions, but combines Nordhaus's gradual implementation of increasingly stringent GHG emission reductions with more serious research into low-probability, high-magnitude ("low-g") events "and what might be done realistically about them should they start to materialize."¹²¹ For now, we simply "lack a commonly accepted usable economic framework for dealing with these kinds of thick-tailed extreme disasters, whose probability distributions are inherently difficult to estimate (which is why the tails must be thick in the first place)."¹²²

Weitzman's conclusion and policy recommendations seem somewhat at odds with his recognition of potential climate-change catastrophes. All else being equal, intuition suggests that serious consideration of low-probability, high-magnitude events would lead to recommendations that favor more rapid and aggressive action to stabilize the climate, as Stern recommends.¹²³ However, Weitzman's thinking on this question is evolving. In a more recent working paper he finds that structural uncertainties inherent in our economic analyses of climate change might call for the application of a "generalized precautionary principle"¹²⁴ to avoid catastrophes that might "drive all of planetary welfare to disastrously low levels in the most extreme scenarios"¹²⁵ (located in the bad, fat tail of the probability distribution function). Therefore, a "CBA of fat-tailed potential catastrophes is inclined to favor paying a *lot* more attention to learning *now* how fat the bad tail might be and – if the tail is discovered to be too heavy for comfort after the learning process – is a *lot* more prone to investing big-budget real money on mitigation measures to slim it down."¹²⁶ Economic analyses that "ignore or suppress the significance of rare tail disasters... ignore or suppress what economic-statistical decision theory is telling us here loudly and clearly is potentially the most important part of the analysis."¹²⁷

Stern and Persson share Weitzman's concern about the bad fat tail of probability density functions for climate change damages, but they think

121. *Id.*

122. *Id.* at 723.

123. Posner seems to agree, recommending emissions limits now as an "insurance policy" against the "possibility of abrupt warming." POSNER, *supra* note 12, at 163. But Posner also notes that emissions limitations, in the form of taxes, need not be terrifically high to have the desirable effect of inducing technological advancement and substitution, which he considers the "only" way to "halt global warming." *Id.* at 161. Moreover, Posner suggests that "[m]aking shallower cuts now can be thought of as purchasing an option to enable global warming to be stopped or slowed at some future time at a lower cost." *Id.* at 162.

124. Weitzman, *supra* note 9, at 24–26.

125. *Id.* at 28.

126. *Id.* at 31.

127. *Id.* at 23.

the tail is even fatter and badder than Weitzman realizes because all of the IAMs, including the *Stern Review's* PAGE2002 IAM, seriously underestimate climate change damages. Specifically, they underestimate nonmarket damages by assuming perfect substitutability for environmental goods that may be degraded or destroyed as a consequence of climate change.¹²⁸ Even if climate change has relatively little effect on conventional manufacturing and economic services, it may significantly damage highly valuable ecosystem services, some of which are "inherently very hard to replace."¹²⁹ Consequently, to provide an accurate picture of future damages, climate change IAMs must anticipate changes in the relative prices of environmental goods and services resulting from resource depletion, degradation, or destruction. Sterner and Persson amend Nordhaus's DICE IAM to show how "taking relative prices into account can have an effect on necessary abatement that is on the same order of magnitude as changing the discount rate."¹³⁰

Contrary to both Weitzman and Sterner and Persson, Tom Schelling argues that the tails of probability density functions for climate change damage functions should not drive policy.¹³¹ While he agrees with Weitzman that "some 'insurance' principle seems to prevail: if there is a sufficient likelihood of sufficient damage we take some measured anticipatory action," Schelling argues that we should "[w]eigh the costs, the benefits, and the probabilities as best all three are known, and don't be obsessed with either extreme tail of the distribution."¹³² Schelling does not give much guidance on how to treat the uncertainties associated with low-likelihood, extreme events such as the collapse of the West Antarctic ice sheet. He only notes, ambiguously, that immediate action and waiting for complete certainty before acting are not our only options.¹³³

F. An Aside: "Safe Minimum Standards" as an Alternative to BCA

Beyond the social discount rate and the factors that comprise it, concern about structural uncertainties might have broader implications about whether standard BCA remains the proper tool for making policy decisions concerning climate change. Structural uncertainties might, instead, favor the use of a "Safe Minimum Standards" (SMS) approach to

128. Sterner & Persson, *supra* note 6, at 9.

129. *Id.* at 14.

130. *Id.* at 12.

131. Thomas C. Schelling, *Climate Change: The Uncertainties, the Certainties, and What They Imply About Action*, 4 *ECONOMISTS' VOICE*, July 2007, at 4, available at <http://www.bepress.com/ev/vol4/iss3/art3>.

132. *Id.* at 4.

133. *Id.* at 5.

regulatory decision making. SMS applies a relatively hard precautionary principle—harder, perhaps, than Weitzman’s “generalized precautionary principle”—by establishing a floor “below which the flow of key ecosystem services should not be permitted to fall.”¹³⁴ The floor could be set to avoid the very kinds of potential discontinuities that complicate efforts to model climate change using traditional BCA.¹³⁵ But just where should the floor be set? It would seem that the same structural uncertainties that vex conventional BCA would also create problems for SMS. The only difference is that SMS utilizes a hard precautionary principle according to which uncertainty would automatically support greater efforts at mitigation and stabilization. In other words, it builds in a higher level of risk aversion. Naturally, economists who prefer not to presume a high level of risk aversion would oppose the hard precautionary principle of SMS and would prefer BCA, either with or without Weitzman’s presumably softer “generalized precautionary principle.” Obviously, much work remains to be done to determine the best means of factoring risk aversion—in particular aversion to potentially catastrophic harms—into economic analyses.

IV. IMPLICATIONS FOR THE THEORY AND PRACTICE OF BCA

What are the implications of the *Stern Review* and its critics for the theory and practice of BCA? There are several potential lessons, which are listed below and only briefly discussed in no particular order of importance. They are all important.

A. Of Confidence and Caveats

Economic analyses of problems and policies at the frontiers of scientific knowledge are bound to be controversial and error prone, especially where time horizons are long and uncertainty looms large. In some cases, they amount to little more than shots in the dark. This is not an

134. Michael Margolis & Eric Nævdal, *Safe Minimum Standards in Dynamic Resource Problems – Conditions for Living at the Edge of Risk 1* (Resources for the Future, Discussion Paper 04-03, 2004).

135. See S.V. CIRIACY-WANTRUP, *RESOURCE CONSERVATION: ECONOMICS AND POLICIES*, ch. 18 (1952) (SMS and BCA may not be mutually exclusive); see also Bryan G. Norton & Michael A. Toman, *Sustainability: Ecological and Economic Perspectives*, 73 *LAND ECON.* 553, 561–63 (1997) (suggesting that SMS can be combined with standard BCA in a “two-tiered” system of policy analysis); Mohan Munasinghe et al., *Applicability of Techniques of Cost-Benefit Analysis to Climate Change*, in *GLOBAL CLIMATE CHANGE: ECONOMIC AND POLICY ISSUES* 33 (Mohan Munasinghe ed., World Bank Environment Paper No. 121995, 1995) (suggesting that BCA “is a generic term that subsumes a wide body of specific techniques”). I am grateful to Ian Hodge for suggesting the comparison of traditional BCA with SMS.

argument against making the effort to economically analyze complex problems like climate change. For such problems all of our approaches to decision making are likely to be controversial and error-prone, and there is little reason to suppose that any other approach would provide policy makers with better quality information than multiple BCAs. Nevertheless, given the special analytical – particularly measurement – problems of long-term, highly complex problems like climate change, authors of BCAs should be especially cautious about the conclusions they draw and the recommendations they make. Nearly all reviewers agree that the Stern group pretended to greater confidence in their comparatively radical conclusions and recommendations than the facts and analysis warranted. While the *Stern Review* contained several warnings about the problems associated with forecasting the costs and benefits of climate change and mitigation, it did not heed its own warnings when presenting its conclusions and recommendations unconditionally.

B. On the Inherently Political Nature of BCAs and the Importance of Sensitivity Analyses

The *Stern Review* is a political and ethical document as much as an economic study. Several reviewers consider this a fault, as if BCAs should be, or ever could be, neutral. All BCAs are, to one extent or another, political or ethical documents. Given the inherently subjective elements of BCA – from the valuations of nonmarket goods (including human lives) to the choice of value parameters (including discount rates) – and given the influence of those subjective elements on outcomes, each and every BCA inevitably is informed by the ethical, political, and/or ideological predilections of its author(s).¹³⁶ The range of subjective choice may (or may not) be bounded by the observed behavior of market actors, but the choices remain inevitably subjective. A chief virtue of BCA as a decision tool is that it makes those predilections transparent (at least compared to other decision tools) because, according to “best practices,” authors are supposed to make their assumptions – including choices of parameter values – explicit.

The authors of the *Stern Review* did not fully meet the standard of transparency. To their credit, they specified parameter values, including the utility discount rate. Even if they chose a rate based on paternalistic ethics that ignored observed economic behavior, at least they were explicit about it and provided reasoned arguments to support it. They were not explicit, however, about their valuations of nonmarket goods, including human lives. Those valuations, just like the discount rate, are subjective and

136. Sterner & Persson, *supra* note 6, at 15–16.

therefore subject to manipulation for political purposes. For that reason, BCA authors must state and support them explicitly.

Because of the potential for subjective elements including parameter values and valuations of nonmarket goods to affect the outcome of BCAs, the *Stern Review* certainly should have included a sensitivity analysis. Sensitivity analyses are helpful in demonstrating the relative robustness of outcomes across alternative valuations. The failure of the *Stern Review* authors to include one in their original BCA was a significant omission, to say the least. In response to their critics, they eventually did prepare what Weitzman has called "a halfhearted sensitivity analysis postscript."¹³⁷ Stern's sensitivity analysis purported to demonstrate the robustness of the *Review's* conclusions but succeeded only in demonstrating their high sensitivity to the choice of parameter values (something that critiques of the *Stern Review* already had demonstrated). Arguably, Arrow provides a more convincing argument for the robustness of the *Stern Review's* conclusions than the *Review's* own sensitivity analysis.¹³⁸

C. On Discounting

Perhaps the most obvious lesson from the *Stern Review* and its critics (at least for those who have not already learned it) is that the choice of parameter values (including discount rates, coefficients of relative risk aversion, and per capita consumption growth rates) can decisively influence the outcome of BCAs. Unfortunately, the *Stern Review* and its critics also remind us of just how far away we remain from being able to specify a consensus "best practice" for selecting parameter values. Many (though by no means all) reviewers complain that the *Stern Review's* choice of a 0.1 percent pure rate of time preference is too low. This assessment is supported by two reasons: (a) such a low discount rate ignores how people actually behave in markets and (b) it deviates significantly from a "conventional range" of discount rates in the BCA literature. These assertions are both true, and yet they do not warrant a conclusion that Stern's choice of discount rate was "wrong" or violated some "best practice" of BCA.

It is obviously true that market participants display implicit discount rates higher than that adopted by the *Stern Review*, but that is neither a necessary nor a sufficient reason for governments to adopt similarly high discount rates in framing policies to deal with long-run social-cost problems, particularly where those problems are largely the

137. Weitzman, *supra* note 1, at 707. For the *Stern Review's* sensitivity analysis, see also STERN, *supra* note 2, at 667.

138. See generally Arrow, *supra* note 6.

result of the short time horizons and high discount rates of market actors.¹³⁹ Moreover, as Stern rightly points out, the choice of a discount rate in regulatory BCA is not just a question of mimicking the market; it is an ethical judgment.

But is it the job—or the right—of a BCA author to make ethical or political judgments that can determine the outcome of the BCA?¹⁴⁰ Some critics of the *Stern Review* suggest not. They believe that the author of a BCA should avoid imposing his or her own ethical values on policy makers. Rather, the author should input the best available data, crunch the numbers in the most neutral way possible, and present the unvarnished results to public officials who are responsible for making policy. Otherwise, the author of the BCA inappropriately usurps the role of policy maker.¹⁴¹ This is a sensible argument but, as suggested above, it is not entirely possible for any author of any BCA to avoid imposing their values on the BCA in ways that affect the outcome simply because of the subjective judgments that each BCA inevitably entails. In other words, every author of every BCA is, to a greater or lesser extent, a would-be policy maker. This is as true of Nordhaus and his three-percent utility discount rate as it is of Stern and his 0.1 percent utility discount rate.¹⁴²

139. See Cole, *supra* note 8, at 6; see also Arrow et al., *supra* note 76, at 5 (explaining that the existence of market imperfections and suboptimal tax policy might justify deviation from observed market rates of interest). From a prescriptive perspective, the fact that a chosen social discount rate is “glaringly inconsistent with observed behavior” (for example, government spending on education or research, development assistance by donor countries) should not be decisive. “[J]ust because the government fails to allocate resources in one area on the basis of ethical considerations is no reason to insist that decisions in other areas be consistent with that initial decision.” *Id.* at 7.

140. Arrow et al., *supra* note 76, at 7, address this question directly, noting that analysts fall into one of two camps: descriptivists, who start from observed market behavior; and prescriptivists, who start from normative ethics. Arrow et al. also describe in detail the different approaches to establishing the social discount rate but do not assert that one is clearly correct or necessarily preferable to the other. In fact, the authors treat both approaches as valid and conclude by finding that, with some refinements, the different approaches could lead to similar policy recommendations. *Id.*

141. See *supra* note 102. Because Stern was a policy maker at HM Treasury, he cannot be accused of “usurping” that role.

142. William Nordhaus has recently revised his DICE model. William Nordhaus, *The Challenge of Global Warming: Economic Models and Environmental Policy* (July 24, 2007) (unpublished manuscript), available at http://nordhaus.econ.yale.edu/dice_mss_072407_all.pdf. Among the most significant changes in DICE-2007, the pure rate of time preference (ρ) is reduced from 3.0 percent to 1.5 percent. *Id.* at 54. In addition, Nordhaus sets the elasticity of the marginal utility of consumption (η) at 2. *Id.* Significantly, Nordhaus expressly recognizes that the same real interest rate would be achieved by combining $\rho = 0.1\%$ (a la the *Stern Review*) and $\eta = 2.9$. *Id.* at 62. Unfortunately, Nordhaus does not specify a value of g (the per-capita growth rate of consumption), so we cannot directly compare his discount rate of consumption with that of the *Stern Review*. Earlier versions of the DICE model assumed values of g declining

As for the “conventional range” of utility discount rates, it is true that the *Stern Review*’s choice of a 0.1 percent pure rate of time preference is lower than the rates chosen in most other BCAs. Does this deviance render it illegitimate? Standard practices can, and sometimes do, become norms that govern decisions, potentially including decisions about parameter values. But Portney and Weyant found no normal social discount rate for BCA,¹⁴³ and the literature since then provides no basis for revising their finding.¹⁴⁴ Even if there were a generally accepted range of discount rates for BCAs, prominent economists have argued that climate change represents a special case—a long-run phenomenon subject to relatively great uncertainties, including uncertainty about the discount rate itself, which could lead to ruinous reductions in the growth rate of per capita consumption—requiring lower-than-usual discount rates.¹⁴⁵

Tom Schelling presents a very different reason for believing that climate change is a special case.¹⁴⁶ In his view, discounting is inappropriate for assessing the costs and benefits of climate change because those who bear the costs are not the same people, generally speaking, who will receive the benefits. The costs of climate change, now and in the future, will fall disproportionately on people in developing countries, but the costs of mitigating GHG emissions to stabilize the climate and reduce the costs of climate change under the Kyoto Protocol or any other reasonably conceivable program will be borne predominantly by the citizens of wealthier, developed countries.¹⁴⁷ Thus, efforts to mitigate climate change are in the nature of a foreign aid program, like the Marshall Plan, NATO, or disease eradication campaigns in Africa. As such, discounting is inappropriate. Schelling writes that “[t]he alleged inborn preference for earlier rather than later consumption is exclusively concerned with the

from 2.3 percent in 2000 to 1.1 percent by 2050. Taking the average of these numbers, $g = 1.7\%$, would yield $r = 4.6\%$, well above the *Stern Review*’s $r = 1.4\%$. Consequently, Nordhaus’s estimates of future damages from climate change and future benefits of GHG mitigation remain far below those of the *Stern Review*, despite Nordhaus’s halving of ρ . Not surprisingly, therefore, Nordhaus still finds the *Stern Review*’s recommendations too costly by far. *Id.* at 29. Where Stern recommends spending one percent of global GDP to mitigate GHG emissions, Nordhaus recommends spending only one-tenth as much (about nine dollars per capita), which would reduce expected global mean temperature increases by 1.71°C over the next century. Nordhaus’s bottom line policy recommendation remains the same: a slow and gradual ramping up of GHG emissions reductions. *Id.* at 36–37.

143. See DISCOUNTING AND INTERGENERATIONAL EQUITY, *supra* note 80, at 1–11.

144. See generally Cole, *supra* note 8.

145. See Weitzman, *supra* note 1, at 717–19; see also Dasgupta et al., *supra* note 84, at 72.

146. Schelling, *supra* note 36.

147. *Id.* at 34–35.

consumer's impatience with respect to his or her *own* consumption."¹⁴⁸ He goes on to note that

decisions to invest in greenhouse gas-emissions abatement for the benefit of future generations are not "saving decisions" — not decisions about postponing one's own consumption — but are instead decisions about redistributing income, one's own income. To invest resources now in reduced greenhouse gas emissions is to transfer consumption from present-day people — whoever those people are who are making these sacrifices — for the benefit of people in the distant future. It is very much like making sacrifices now for people who are distant geographically or distant culturally.¹⁴⁹

If Schelling is right about this,¹⁵⁰ then Stern and Cline were right to adopt zero (or nearly zero) values of ρ . This does not mean, however, that Schelling necessarily would concur in their conclusions or recommendations. In fact, Schelling favors a gradual approach to GHG reductions over time.¹⁵¹

A final response to the argument from convention is that the *Stern Review's* 0.1 percent pure rate of time preference is not unprecedented among climate change BCAs. The pioneering economic analysis of Cline adopted a pure rate of time preference of 0.0 percent.¹⁵² Taken together, the ethical arguments of Ramsey (among others),¹⁵³ the conceptual arguments of Schelling,¹⁵⁴ Portney and Weyant's evaluations of practice,¹⁵⁵ and Cline's application counsel against a conclusion that there is a "best practice," convention, or social norm that the *Stern Review* violated in adopting a 0.1 percent pure rate of time preference. Even if there were such a norm, its violation would not, by itself, make much difference to the overall BCA. As

148. *Id.* at 52. Presumably, the same logic would militate against inter-generational discounting.

149. *Id.* at 53.

150. Posner explicitly agrees with Schelling that "[f]rom the standpoint of the American public, the Kyoto Protocol would be a foreign-aid program." POSNER, *supra* note 12, at 126. But later, Posner implicitly argues that not all investments in climate change should be thought of as foreign aid because abrupt global warming "could be catastrophic for the wealthy as well as for the poor countries and cannot be assumed to threaten merely in the distant future." *Id.* at 256. But even if investments in climate change prevention do not constitute foreign aid, Posner asserts that we might choose "to dispense with explicit discounting altogether" because abrupt climate change could "happen soon enough to make discounting unimportant in deciding whether we should take steps to avert it." *Id.*

151. See Schelling, *supra* note 36.

152. See CLINE, *supra* note 3, at 249–50.

153. See *supra* notes 75–76 and accompanying text.

154. See generally Schelling, *supra* note 36.

155. See *supra* note 80 and accompanying text.

Weitzman demonstrates,¹⁵⁶ it is not the pure rate of time preference (ρ) alone that is significant, but the combination of parameter values for ρ , η , and g that together determine r , the consumption rate of discount. The pure rate of time preference is only one factor of the Ramsey equation. And it is the product of that equation, r , that ultimately has significance for the BCA.

Nevertheless, three concerns remain about the *Stern Review's* discount rate. Those concerns relate to other arguable conventions, social norms, or "best practices" in BCA. First, in selecting a pure rate of time preference, the *Stern Review* summarily ignored HM Treasury's own *Green Book* of discount rates.¹⁵⁷ Interestingly, the *Green Book's* schedule closely tracks Nordhaus and Boyer's model, with a range of discount rates that decline from 3.5 percent (for costs and benefits between year zero and year 30) to one percent (for costs and benefits arising after 300 years). Stern makes only a couple of references to HM Treasury's *Green Book*¹⁵⁸ and does not provide anything like a sufficient explanation as to why the authors chose to ignore the discount rates *mandated* by their own Ministry. This should be deemed a violation of a "best practice" standard according to which government agencies must follow their own rules, unless they provide a thorough and transparent explanation justifying deviation. Not doing so generates at least two problems: (a) it creates the appearance (at least) that something fishy is going on in the BCA and (b) it unjustifiably erodes the authority of government policy makers.

Second, in rejecting the schedule of discount rates set forth in HM Treasury's *Green Book*, the *Stern Review* rules out, without discussion, the use of hyperbolic discounting, which more and more economists believe should be the norm for assessing policies with long-term effects. An increasing body of empirical evidence suggests that people discount future costs and benefits hyperbolically, using higher rates of discount for near-term costs and benefits than for longer-term costs and benefits.¹⁵⁹ For long-term events like climate change, several economists have concluded that hyperbolic discounting is more appropriate than discounting at any single value of r .¹⁶⁰ A few years ago, Weitzman surveyed more than 2,000 of his fellow economists about their "professionally considered gut feeling"

156. See *supra* note 97 and accompanying text.

157. HM TREASURY, THE GREEN BOOK: APPRAISAL AND EVALUATION IN CENTRAL GOVERNMENT (2003), available at http://greenbook.treasury.gov.uk/media/3/F/green_book_260907.pdf.

158. See STERN, *supra* note 2.

159. See W. Kip Viscusi & Joel C. Huber, *Hyperbolic Discounting of Public Goods* (Nat'l Bureau of Econ. Research, Working Paper No. 11935, 2006), available at <http://www.nber.org/papers/w11935>; Maureen L. Cropper et al., *Preferences for Life-Saving Programs: How the Public Discounts Time and Age*, 8 J. RISK & UNCERTAINTY 243 (1994).

160. See, e.g., Larry Karp, *Global Warming and Hyperbolic Discounting*, 89 J. PUB. ECON. 261 (2005); Moore et al., *supra* note 42.

concerning the appropriate social discount rates for measures to mitigate climate change. Weitzman aggregated their responses and found support for a discount rate (r) that declines from four percent (in years one through five) to one percent (after 75 years) and to zero percent (after 300 years).¹⁶¹ As we have seen, William Nordhaus's DICE model for climate change utilizes hyperbolic discounting. And the PAGE2002 model used by the *Stern Review*'s authors is compatible with hyperbolic discounting. However, Stern rules out the possibility of hyperbolic discounting by adopting an extremely low discount rate even for the nearest-term effects of climate change. Arguably, the *Stern Review* should not have rejected hyperbolic discounting without at least discussing and providing reasons against it. The discussion could have been quite brief, along the following lines: hyperbolic discounting only makes sense if one is beginning from a relatively high discount rate for near term effects; given that the *Stern Review* was beginning with a very low discount rate, there was no need and little purpose to be served by reducing that rate over time.

Third and finally, it has become common over the last decade or more for government agencies, at least in the United States, to prepare BCAs incorporating multiple calculations using various discount rates.¹⁶² This practice has the benefit of presenting policy makers with more information and a clearer understanding that they have a choice of parameter values and how that choice affects expected valuations of future costs and benefits and ultimate outcomes. The *Stern Review*'s authors might at least have presented alternative calculations using HM Treasury's official

161. Martin Weitzman, *Gamma Discounting*, 91 AM. ECON. REV. 260, 270 (2001). Even if hyperbolic discounting is observed in practice, some argue that it is problematic as a matter of economic theory because it implies time-inconsistent plans. See, e.g., Maureen Cropper & David Laibson, *The Implications of Hyperbolic Discounting for Project Evaluation* 1 (World Bank Policy Research, Working Paper No. 1943, 1998), available at <http://ssrn.com/abstract=629111> (follow the "download document" link, last visited Mar. 3, 2008); Ben Groom et al., *Declining Discount Rates: The Long and the Short of It*, 32 ENVTL. & RES. ECON. 445, 446-47 (2005). To see why, assume a plan made in 2007 with effects extending over 100 years. According to Weitzman's schedule of declining discount rates, the effects in year 2083 would be discounted at a one-percent rate. See Weitzman, *supra*. However, as 2083 approached, our rate of discount for those effects would rise in accordance with the discounting schedule, potentially altering our plans. Some economists believe this is an insignificant problem. Heal, for example, notes that individuals making plans at different times might as well be thought of as different individuals. GEOFFREY HEAL, *VALUING THE FUTURE: ECONOMIC THEORY AND SUSTAINABILITY* (1998). Newell and Pizer, *supra* note 101, contend that even if time inconsistency of individual preferences is a problem, hyperbolic discounting ceases to present that problem if it is based not on individual preferences but on uncertainty over future events. As a practical matter, time-inconsistency is probably no more problematic than policy changes resulting from exogenous shocks or political shifts. See Groom et al., *supra*.

162. See, e.g., EPA, *THE BENEFITS AND COSTS OF THE CLEAN AIR ACT, 1970-1990* (1997), available at http://www.epa.gov/air/sect812/1970-1990/chptr1_7.pdf.

schedule of declining discount rates in addition to its own preferred parameter values. Given the inherently subjective nature of those values, we might call for the adoption of a "best-practice" standard requiring not just sensitivity analyses, but alternative sets of complete calculations under various parameter values, perhaps including a presentation of the stream of non-discounted future costs and benefits.

The same effect can be obtained – and arguably is obtained in the case of climate change BCAs – by the independent generation of multiple BCAs assessing the same social problems and policies utilizing different parameter values. The *Stern Review* is not the only economic analysis we have of climate change.¹⁶³ The fact that other BCAs of climate change exist arguably reduces the significance of the omissions, miscalculations, and idiosyncrasies of any one set of analyses, conclusions, and recommendations. The various economic analyses and their critiques are all available, along with this and other meta-analyses, in the "marketplace of ideas"¹⁶⁴ to inform policy makers. In this respect, the *Stern Review's* "deviance" from other economic analyses of climate change might be viewed as an advantage, providing policy makers with a significantly different but not obviously illegitimate view of the same problem.¹⁶⁵

D. What's a Human Life or a Functional Ecosystem Worth?

Even if the *Stern Review's* exceptionally high damage estimates are completely explained by the choice of parameter values, its failure to plainly specify assumed valuations of non-market goods, including human lives, is a glaring omission that certainly violates "best practices."¹⁶⁶ Given

163. See, e.g., CLINE, *supra* note 3; NORDHAUS & BOYER, *supra* note 3; Mendelsohn et al., *supra* note 3.

164. *Keyishian v. Bd. of Regents*, 385 U.S. 589, 603 (1967). The phrase is often mistakenly attributed to Justice Oliver Wendell Holmes' dissent in the earlier case of *Abrams v. United States*, 250 U.S. 616 (1919). While Holmes clearly articulated the idea, using expressions like "free trade in ideas," he did not use the precise phrase "marketplace of ideas."

165. The physicist Francesco Calogero suggested something similar when he recommended that the Brookhaven National Laboratory commission two separate assessments of the risk of a catastrophic accident from the potential production of "strangelets" at its particle accelerator. Specifically, he recommended that a "blue team" of experts be appointed to make an "objective assessment," while a separate "red team" of experts played the role of "devil's advocate," coming up with high-danger scenarios that would challenge the "blue team." Francesco Calogero, *Might a Laboratory Experiment Destroy Planet Earth?*, 25 INTERDISC. SCI. REVS. 191, 192–93 (2000), discussed in POSNER, *supra* note 12, at 190. As Posner notes, Calogero's recommended approach envisioned "an adversary procedure similar to the clash of party-designated expert witnesses at trial." *Id.* at 190.

166. Valuations of non-market goods, including human lives, are not important for every BCA. However, where a BCA depends heavily on such valuations, as the *Stern Review* clearly does, then it becomes essential for those valuations to be clearly and fully presented.

the presumed importance of those values for the damage estimate, their absence from the analysis is both perplexing and troubling. A reader of the *Stern Review* has no way of determining whether (a) the author's valuations are based on existing studies or their own best guesses, (b) the valuations are similar to or deviate significantly from those supported in the literature, and (c) the total damage estimates are calculated properly based on those valuations. Lacking valuations of nonmarket damages, no subsequent analyst could even attempt to replicate the *Stern Review's* damage assessment. It is a given that any good BCA should provide enough information for other analysts to replicate its results. In this respect, at least, the *Stern Review* is not a good BCA.

E. Finally, a Couple of Positive Implications of the *Stern Review*

The implications of the *Stern Review* for the theory and practice of BCA are not entirely negative. Arguably, it has made one or two highly valuable positive contributions to the field. For one, it has demonstrated the potential importance of paying attention not only to the mean of expected values of present and future costs and benefits but also to low-probability, high-magnitude (potential "low-g") events at the tails of damage distribution curves. As Weitzman notes,¹⁶⁷ events that are highly unlikely may nevertheless be so significant for future consumption growth rates that they simply must be accounted for in economic analyses. Nordhaus and Boyer paid some attention to potentially catastrophic climate-change events,¹⁶⁸ but the *Stern Review* is the first to focus its entire BCA beyond the mean estimate of damages (including damages to non-market goods).

Accounting for high-damage scenarios (beyond mean estimates) may not be important for economic analyses of standard, run-of-the-mill government policies and projects. But for arguably special cases like climate change, which combine unusually long time-horizons with very high levels of Knightian uncertainty, worse-case scenarios should be treated seriously. This, itself, constitutes a kind of precautionary principle.¹⁶⁹

A second positive lesson from the *Stern Review* for the practice of BCA is not to be found in the *Review* itself, but in Sir Nicholas Stern's willingness to engage his critics. As noted earlier, one of the major failings of the *Stern Review*, as originally published, was the absence of a sensitivity analysis to demonstrate the robustness of its conclusions across alternative parameter values. Stern responded by adding a sensitivity analysis to the

167. Weitzman, *supra* note 1.

168. See NORDHAUS & BOYER, *supra* note 3.

169. Weitzman asserts that cases like climate change, which involve structural uncertainties and the potential for catastrophic events, may require the imposition of a "generalized precautionary principle." Weitzman, *supra* note 9, at 22-24.

Review as a postscript. Weitzman may be right that the postscript was a "half-hearted" effort to placate the critics,¹⁷⁰ but at least the *Stern Review's* authors did it (and, of course, it was the right thing to do). Sir Nicholas Stern, as lead author of the *Stern Review*, has also made himself available for conferences and meetings devoted to criticizing his *Review*. For example, on February 15, 2007, Sir Nicholas participated in a conference at Yale, where he confronted some of his staunchest critics, including William Nordhaus and Robert Mendelsohn. Not every author of every BCA would have been so brave or open to disputation.

Stern's willingness to engage his critics reminds us that economic analysis is a dynamic, iterative process, where the cycle of analysis and criticism leads to improved analyses and further criticisms. In other words, no BCA is an island. All *ex ante* economic analyses are provisional, contestable, and revisable. They are in the nature of predictions, which are bound to prove, on any *ex post* evaluation, more or less erroneous (which, again, is not an argument against making the effort). The goal is to minimize the likely range and amplitude of error. Stern explicitly recognizes the provisional nature of *ex ante* BCAs in acknowledging that the *Stern Review* is but "one contribution to [a] discussion."¹⁷¹

V. CONCLUSION

Anyone interested in BCA as a discipline should read both the *Stern Review* and its serious academic critics because they raise serious issues about the practice and practicability of BCA for long-run problems and policies with potentially severe consequences under high levels of Knightian uncertainty. Stern takes a strong position that such uncertainty is not an excuse for inaction, especially where the stakes are enormous, as is arguably the case with climate change. Whatever its analytical flaws, Stern is surely right about that most important point, as Weitzman notes.¹⁷²

The *Stern Review* arguably carries special weight because it was published as an official government document under the auspices of HM Treasury. That can be the only reason for the extraordinary media attention its publication received, in stark contrast to other economic analyses of climate change quietly produced by university-based academics. The *Stern Review's* government imprimatur created the risk that the *Review* might disproportionately influence public policy not because of its merits relative to other economic analyses but because of its pedigree. The implications of that risk for the theory and practice of BCA are unclear. Perhaps we can

170. See Weitzman, *supra* note 1, at 7.

171. STERN, *supra* note 2, at 163.

172. Weitzman, *supra* note 1, at 723.

take solace in the fact that after the initial surge of public and media enthusiasm over the *Stern Review*, it has not significantly influenced policy in Britain or elsewhere but has taken its place alongside other economic analyses in the relative obscurity of academic discussions such as this one.¹⁷³

At the same time, the *Stern Review* seems to have influenced how other economists, including some of the *Stern Review*'s staunchest critics, approach the economics of climate change. After slamming the *Review* when it was first published, Tol and Yohe more recently have suggested that Stern and his co-authors "may be right" (albeit "for the wrong reasons").¹⁷⁴ Weitzman always suspected that might be the case.¹⁷⁵ While critical of the *Stern Review*'s choice of parameter values, Weitzman thought Stern was right to focus more attention on the potential for climate change catastrophes. Since the *Stern Review* was published, Weitzman has been working to improve the treatment of low-probability catastrophes in climate change IAMs.¹⁷⁶ Nordhaus, meanwhile, has amended his own DICE IAM to reduce the pure rate of time preference (ρ) in half from 3 to 1.5, although it is not clear whether the *Stern Review* played any role in this decision.¹⁷⁷

It is worth wondering how much more influential the *Stern Review* might have been if the authors had (a) incorporated a sensitivity analysis prior to publication; (b) rendered the calculations easily replicable by, among other things, specifying valuations of nonmarket goods, including human lives; and (c) presented its conclusions and recommendations with less certainty and more modesty, in keeping with Stern's own cautions about interpreting results from admittedly imperfect and fallible models.¹⁷⁸ To his credit, Stern never claimed that his conclusions and recommendations were the final word on the economics of climate change. He claimed only to be making "a contribution to the discussion."¹⁷⁹ Judged as such, the *Stern Review* may be the most important contribution so far to the economics of climate change.

173. I do not mean to suggest that inattention to the problem of climate change is a good thing, only that policy should not be unduly influenced by a single, methodologically flawed BCA.

174. Yohe et al., *supra* note 66 and accompanying text.

175. Weitzman *supra* note 1, at 710.

176. See Weitzman, *supra* note 9.

177. See *supra* note 142. In private correspondence, Nordhaus confirms only that he made the change in order to simplify his model. E-mail message from William Nordhaus to Daniel H. Cole (Oct. 17, 2007) (on file with author).

178. STERN, *supra* note 2, at 161.

179. *Id.* at 657.